Flavor Asymmetry of the Nucleon Sea and W-Boson Production*

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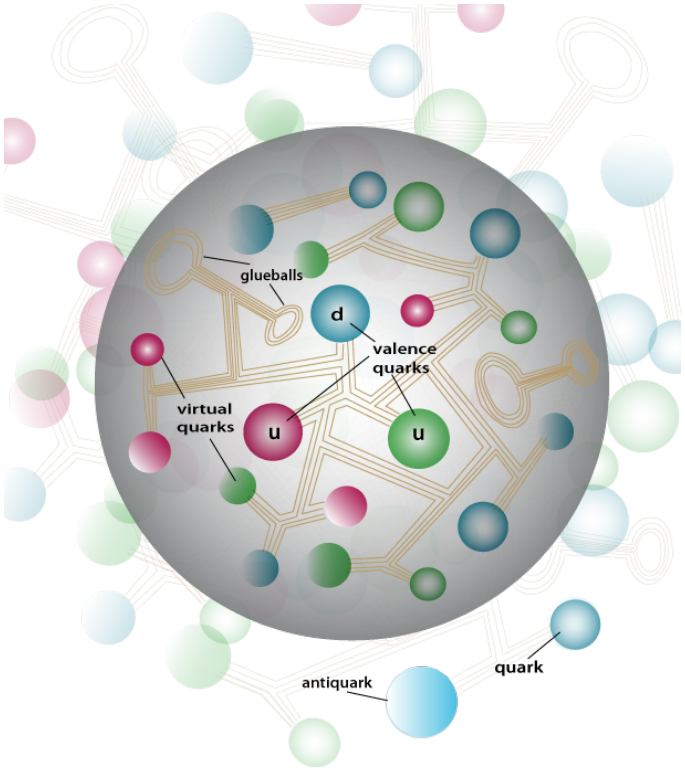
*R. Yang, J.C. Peng, M. Grosse-Perdekamp, Phys. Lett. B 680 (2009) 231-234

What is the Nucleon Sea?

- Parton Model
  - Particles built out of partons (quarks and gluons)
  - Sea quarks caused from splitting of gluons into $q\bar{q}$ pairs



- Is sea flavor independent of valence quarks?
  - Evidence for $s\bar{s}$ production half of $u\bar{u}$

How Do We Measure the Asymmetry?

The Gottfriend Integral, defined below, is a direct measure of flavor asymmetry.

$$I_G = \int_0^1 \frac{[F_2^p(x) - F_2^n(x)]}{x} dx \tag{1}$$

$$F_2^p(x) = x \sum_i e_i^2 (q_i + \bar{q}_i) \tag{2}$$

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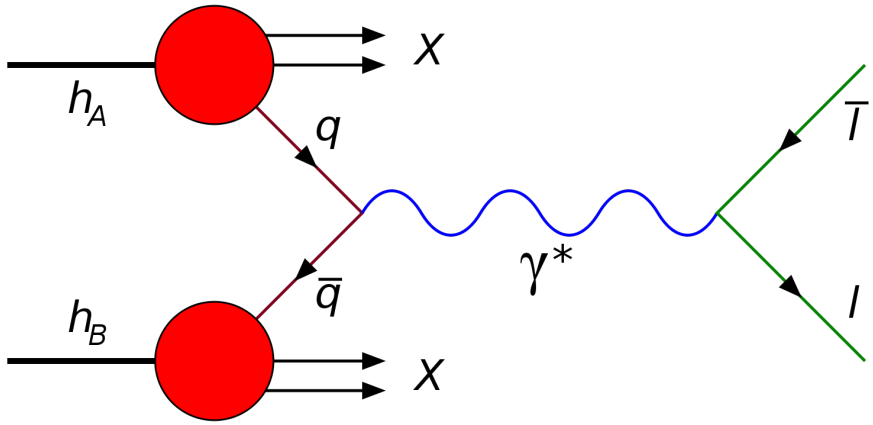
- New Muon Collaboration measured F_2^p, F_2^n over $0.004 < x < 0.8$
  - Calculated $I_G = 0.235 \pm 0.026$
  - More likely that $\bar{u} \neq \bar{d}$ than extreme behavior of structure functions at small x

Alternative Methods to Measure the Asymmetry



- Drell-Yan Scattering is $q\bar{q}$ annihilation in hadron collision
- Can be used to measure asymmetry at specific x
- Cross section of $p + p$ and $p + d$ measured at Fermilab

$$\frac{\sigma_{DY}(p+d)}{2\sigma_{DY}(p+p)} = \frac{1 + \frac{\bar{d}(x)}{\bar{u}(x)}}{2} \tag{4}$$

- Ratio different from unit across $0.015 < x < 0.35$ indicating excess of $\bar{d}$

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  - W production is sensitive at larger scales: $Q^2 \approx 6500 GeV^2/c^2$

Ratio of $W^{\pm}$ cross-sections are sensitive to $\bar{u}$ and $\bar{d}$

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$$\frac{d\sigma}{dx_F}(W^+) = \alpha \left(\frac{x_1 x_2}{x_1 + x_2} \right) \left(u(x_1)\overline{d}(x_2) + \overline{d}(x_1)u(x_2) \right) + strange \tag{5}$$

$$\frac{d\sigma}{dx_F}(W^-) = \alpha \left(\frac{x_1 x_2}{x_1 + x_2} \right) \left(\overline{u}(x_1)d(x_2) + d(x_1)\overline{u}(\chi_2) \right) + strange \tag{6}$$

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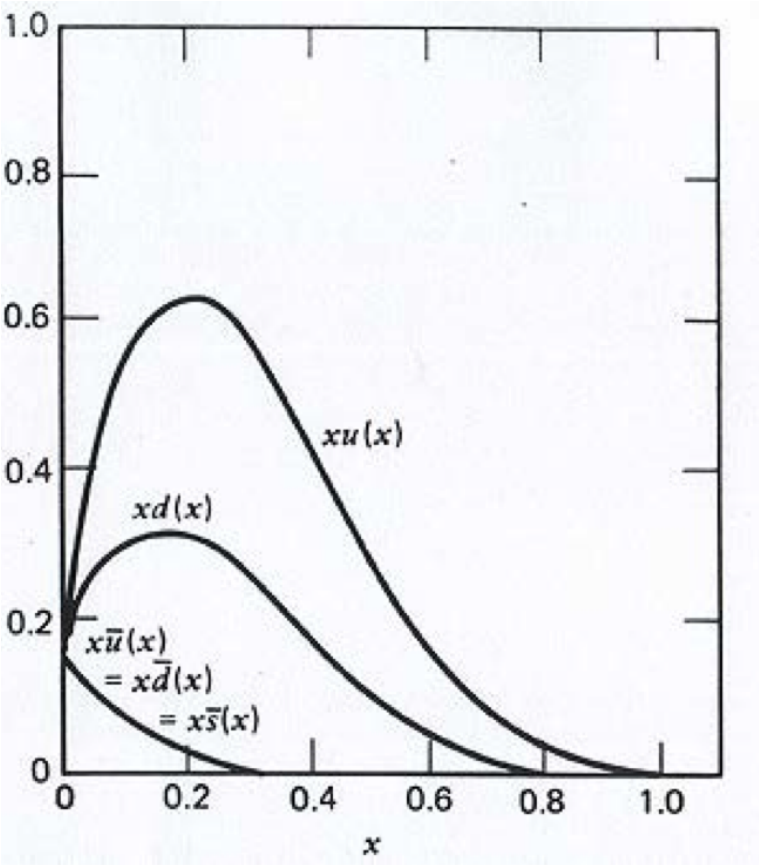
The ratio of these cross-sections are sensitive to $\bar{u}$ and $\bar{d}$ distributions:

$$R(x_F) = \frac{\frac{d\sigma^+}{dx_F}}{\frac{d\sigma^-}{dx_F}} = \frac{u(x_1)\overline{d}(x_2) + \overline{d}(x_1)u(x_2)}{\overline{u}(x_1)d(x_2) + d(x_1)\overline{u}(x_2)} \tag{7}$$

At extreme fractional momentum, R can be simplified

Examining the quark distributions as with fractional momentum



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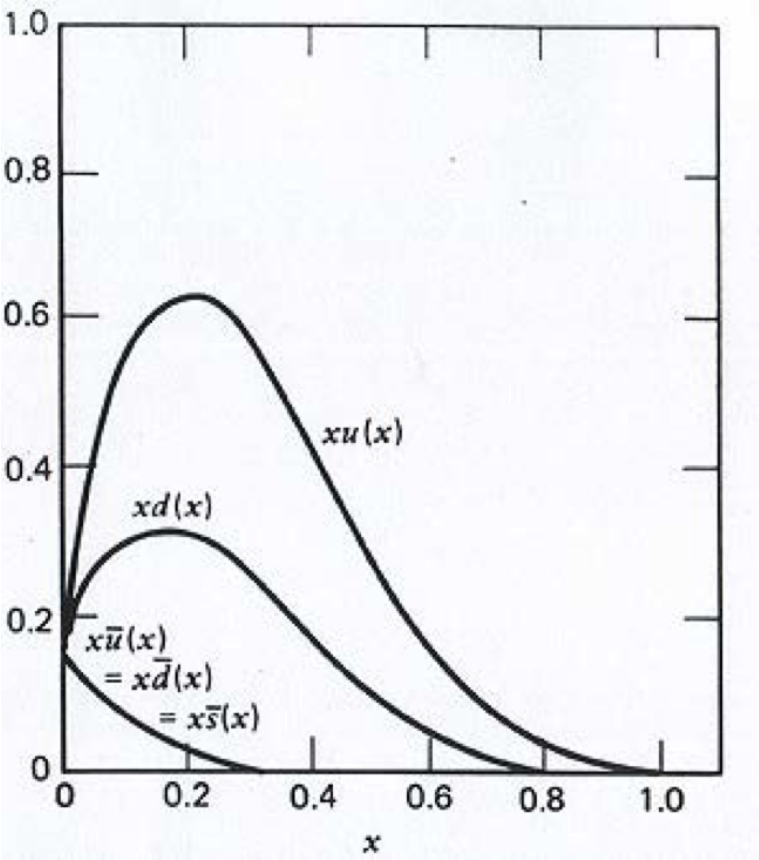

At large $x_F = x_1 - x_2$, the ratio of cross-sections is directly dependent on $\bar{d}/\bar{u}$:

$$R(x_F >> 0) \approx \frac{u(x_1)}{d(x_1)} \frac{\bar{d}(x_2)}{\bar{u}(x_2)} \qquad (8)$$

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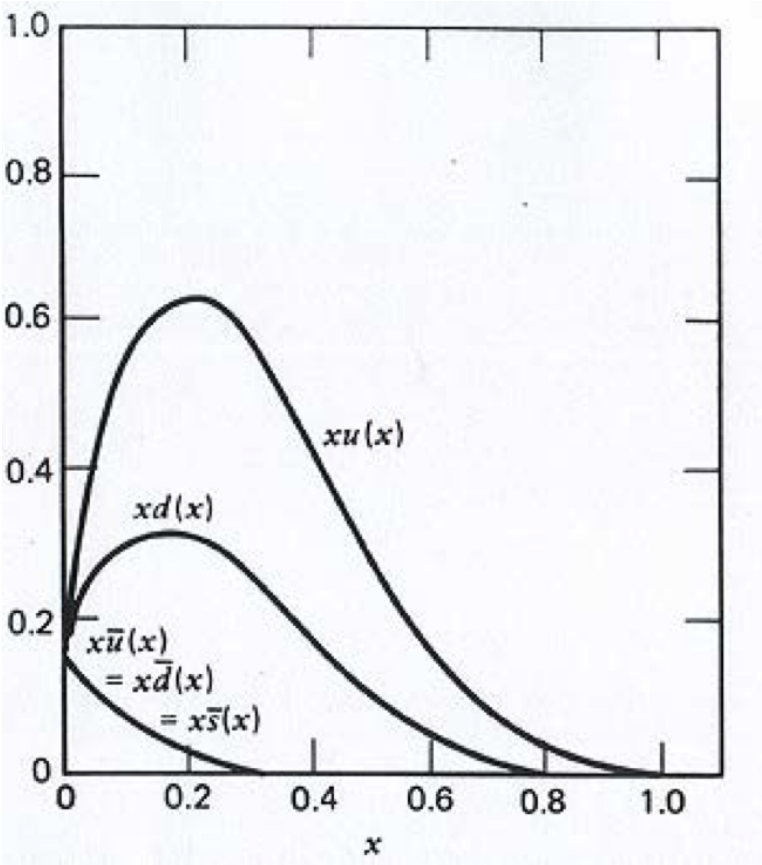

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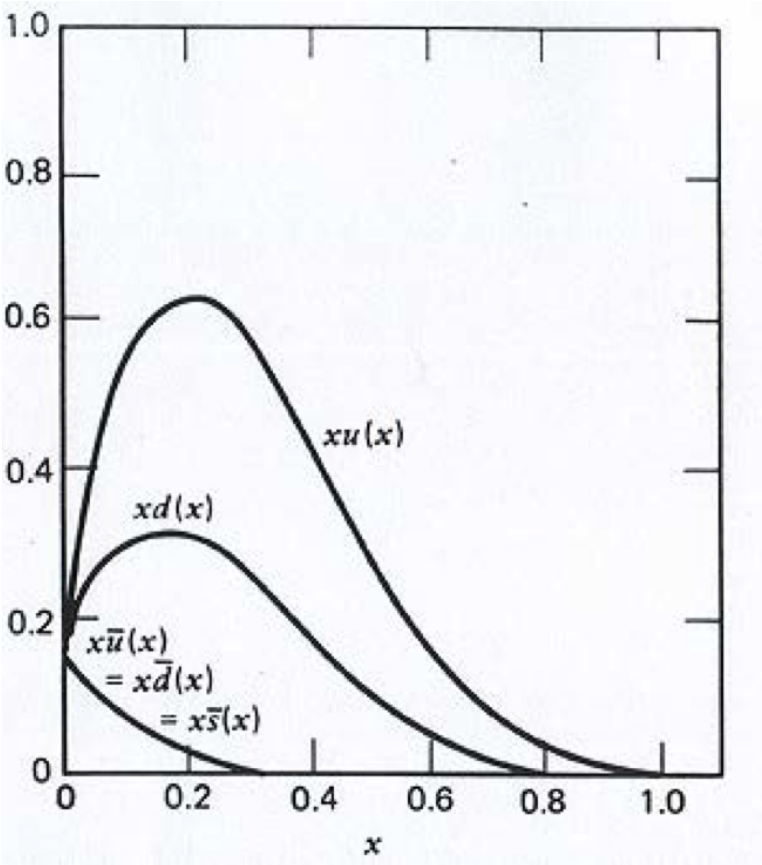

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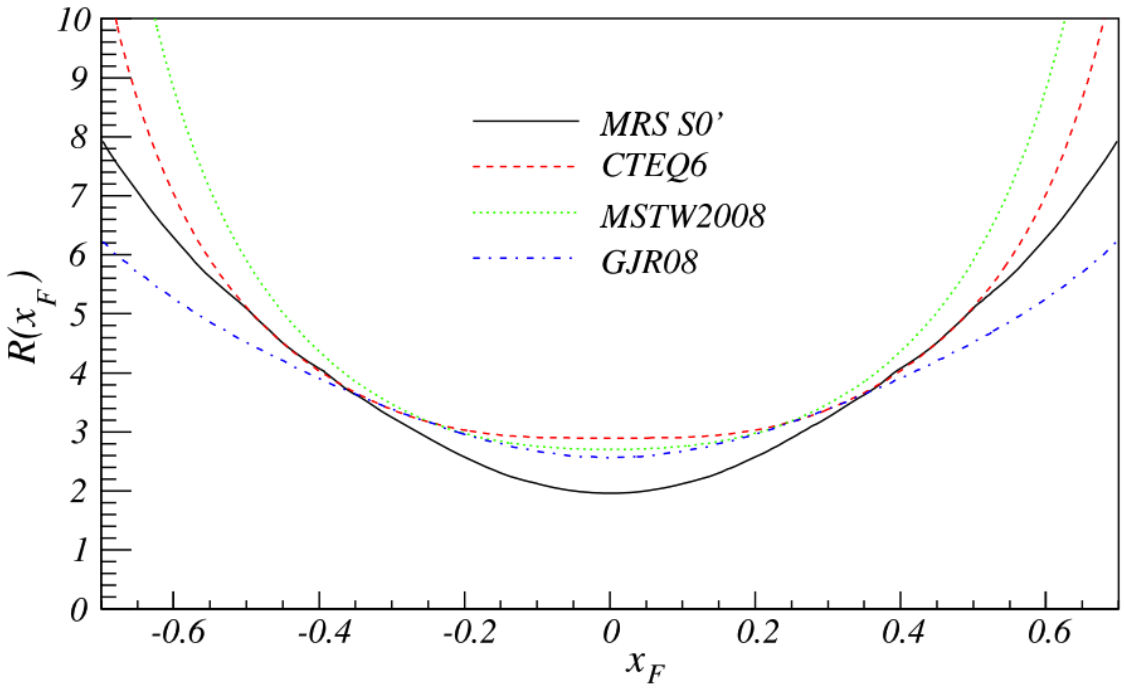
- $\frac{u(x)}{d(x)}$ ratios have been well measured.

Prediction of ratios show sensitivity to flavor asymmetry

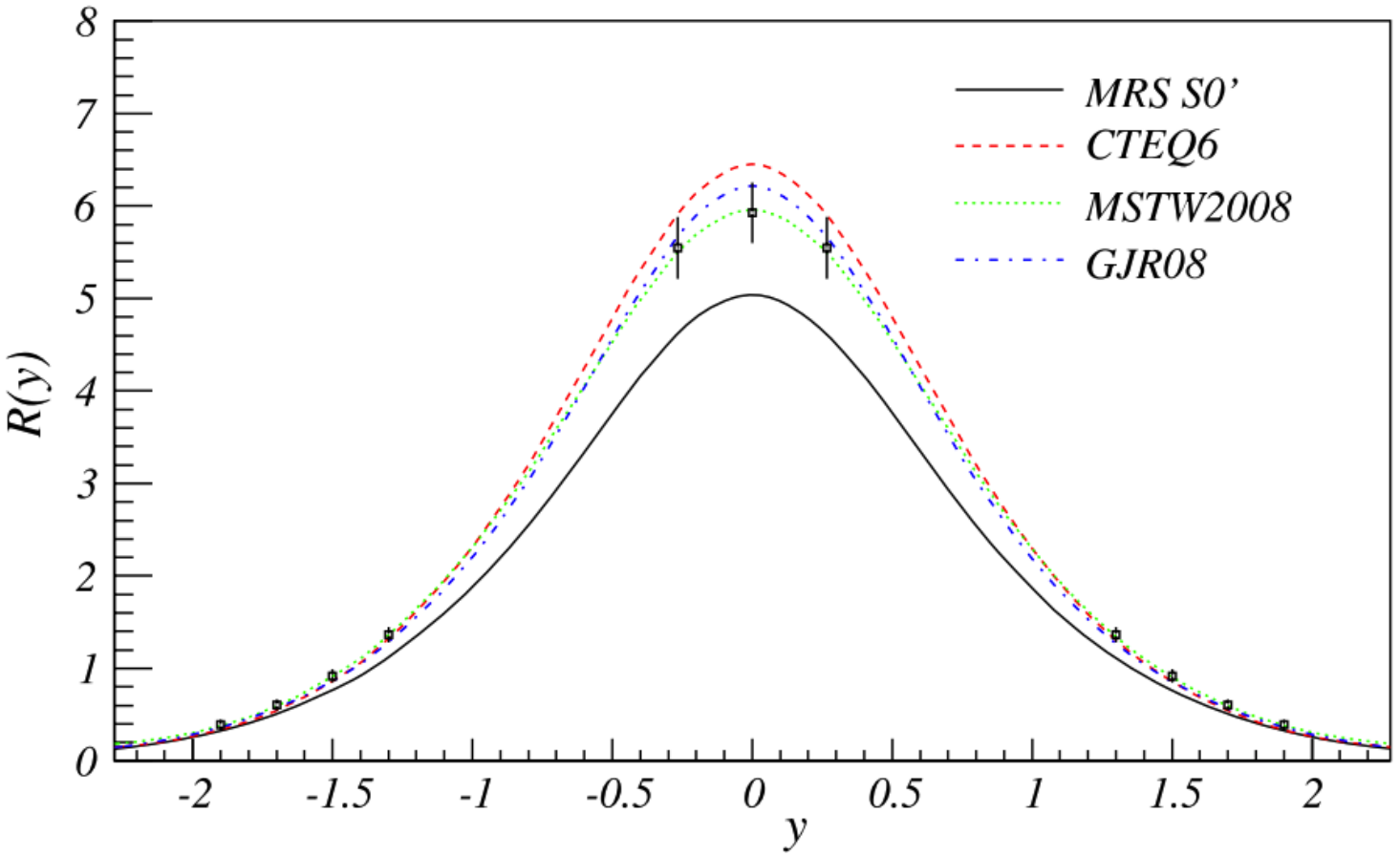
Ratios were computed using several parton distribution functions (PDFs). In particular the black solid line corresponds to no flavor asymmetry while the dashed colored lines are ratios computed using experimental data from E866 collaboration.

For $\sqrt{(s)} = 500 GeV$ (RHIC) [1]:



Lepton cross-section ratio is also sensitive to asymmetry at 500 GeV

What is measured, however, is the charged leptons decaying from the $W^{\pm}$ bosons. The ratio of cross-sections is still sensitive to flavor-asymmetry [1]:



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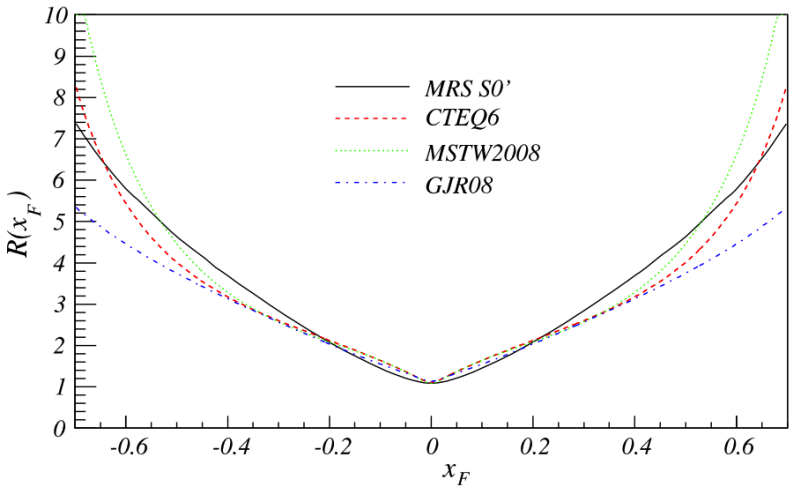

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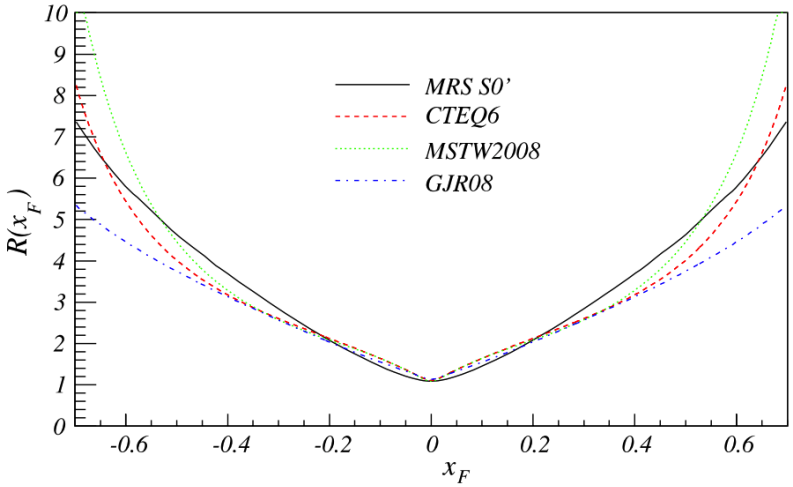

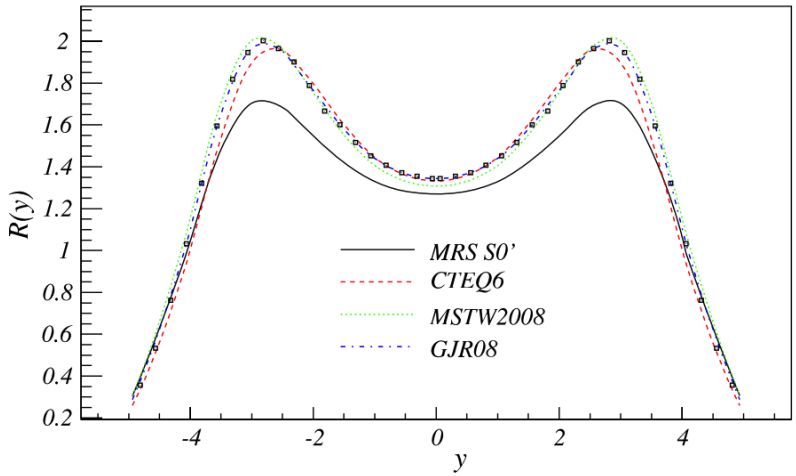

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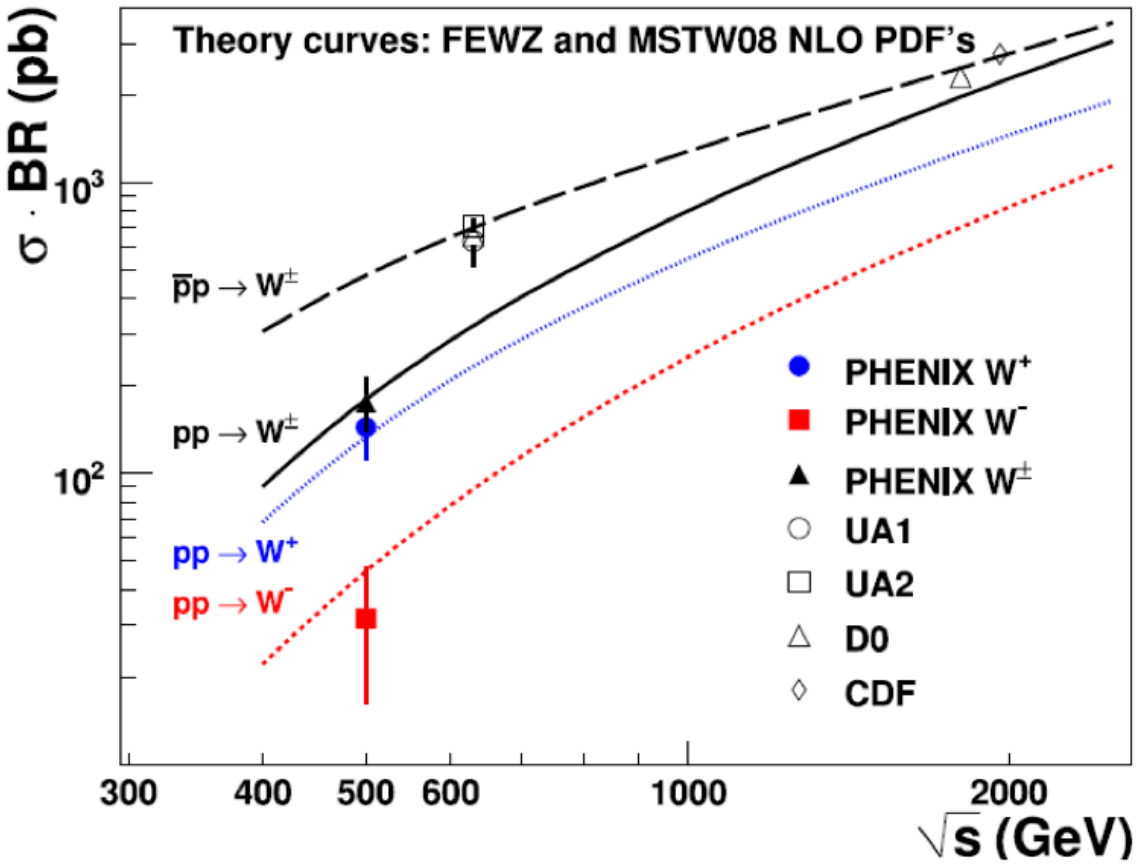
The ratio of lepton cross-sections still remain sensitive to flavor asymmetry.

Recent Results

- The STAR and PHENIX collaboration at the RHIC have both gathered data indicating a preferred cross section for W^+ production in accordance with the results of this paper [3],[4],[5]:



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- Still others: chiral models, instanton models, lattice QCD...

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- Measurements of the cross section ratio of $W^+ \to l^+$ and $W^- \to l^-$ production in $p + p$ collisions will provide a sensitive test of current PDFs.
- Possible experiments can be carried out using existing detectors at RHIC and LHC in the near future.

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  - However... after talking to J. C. Peng, it became more clear that these instances were common knowledge considering the audience for which the paper is written.

References and Acknowledgements

[1] R. Yang, J.C. Peng, M. Grosse-Perdekamp, Phys. Lett. B 680 (2009) 231-234
[2] J. C. Peng, SSP2009 Taipei June 2-5 2009
[3] M. M. Aggarwal et al., arXiv:1009.0326 [hep-ex]
[4] A. Adare et al., arXiv:1009.0505v2 [hep-ex]
[5] L. Adamczyk et al., Phys. Rev. D. 85 092010 (2012)
[6] G. T. Garvey, J. C. Peng, arXiv:0109010v1 [nucl-ex]

Online image sources: http://www.psc.edu/science/2009/qcd/
http://en.wikipedia.org/wiki/File:Drell-Yan.svg

We would like to thank:

- Dr. Lance Cooper
- Dr. Jen-Chieh Peng

Summary and questions

- Measurements of Gottfriend Integral using DIS and DY indicate $\bar{u} \neq \bar{d}$.
- $W^{\pm}$ production available to the LHC and RHIC provides an advantageous method of probing flavor asymmetry.
- $W^{\pm}$ cross-section ratio from recent RHIC data indicates preference for $\bar{d}$.
- There are several explanations for flavor asymmetry although it is open ended.
- The paper was well written for the intended audience and the author was more than helpful in explaining the background.

Questions?

Charge Isospin Symmetry

- Proton/Neutron and Up/Down quarks related under isospin rotations.
- Isospin symmetry assumes that the sea quark production of proton and neutron is similarly related
  - $u_p(x) = d_n(x), d_p(x) = u_n(x)$
  - $\bar{u}_p(x) = \bar{d}_n(x), \bar{d}_p(x) = \bar{u}_n(x)$